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Impact of "Grain to green" programme on echinococcosis infection in Ningxia Hui Autonomous Region of China

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Abstract

Cystic echinococcosis (CE) is endemic among the human population of Xiji County, Ningxia Hui Autonomous Region, China, where the prevalence is estimated to be between 2.2% and 3.6%. Government-run sheep abattoirs in Xiji County have closed in recent years and, as a consequence, slaughter is carried out mostly at rural market places. The market place in Xinglong Township, Xiji County, is home to an increasing number of stray dogs and the lack of government control over slaughter practices potentially favours *E. granulosus* transmission. A survey of sheep, goats and cattle reared in Xiji County was conducted in Xinglong Market and Xinglong Township to determine prevalence and transmission dynamics of *E. granulosus* infection. The liver and lungs of all livestock aged one year and older were examined macroscopically post mortem; visual examination and palpation of organs determined overall prevalence of *E. granulosus*. Cysts consistent in appearance with *E. granulosus* were observed in 2/184 sheep (prevalence 1.0%) and 1/55 of the cattle examined (prevalence 1.8%); 0/13 goats were found to be infected. However, microscopic examination of these suspected cysts failed to confirm these samples as *E. granulosus*, giving a prevalence of confirmed infection of zero percent in all three species. The prevalence of liver fluke was 61.3% in sheep and 12.7% in cattle with a significant difference between males and females($p \leq .001$). Considering the high prevalence of echinococcosis in the local human population, the absence of CE observed among commercially slaughtered livestock was surprising. Several explanations for this discrepancy and their implications are proposed.

1. Introduction

Species in the genus *Echinococcus* are actively transmitted in diverse ecosystems from the arctic tundra to sub-tropical regions making echinococcosis among the most geographically widespread of the zoonotic parasitic diseases (Craig et al., 2007).The global burden of CE has been estimated at 1,009,662 disability-adjusted life years (DALYs) for the years 1996 to 2003 (Budke et al., 2006) and 144,000DALYs in 2010 (Murray et al., 2013). In addition to the impact on human health, the disease is associated with considerable economic loss to agriculture and worker productivity (Torgerson et al., 2000; Torgerson, 2003; Budke et al., 2004; Budke et al., 2005; Majorowski et al., 2005) as the intermediate hosts of CE are generally food-producing animals(Eckert et al., 2001). Transmission is generally facilitated where local slaughter practices are poorly regulated, stray dog populations are high and knowledge of transmission factors is poor (Yang et al., 2006a).

China is the largest producer of sheep meat in the world (FAOSTAT, 2012). With rural pastoral communities at an increased risk due to the synanthropic host-parasite transmission cycle of *Echinococcus* (Craig et al., 2007), the population at risk is 60 million people in 22 provinces (Ito et al., 2003).The number of people infected with CE is estimated to be between 600,000 and 1.3 million (Ito et al., 2003) with an associated US$146,129,587 income loss based on per capita gross national income (Budke et al., 2006).

Ningxia Hui Autonomous Region (NHAR) is located in north-western China bordering Inner Mongolia to the north and Gansu Province to the west. *E. granulosus* is endemic in NHAR, highly endemic in Xiji County (Yang et al., 2006b), and transmission occurs via a sheep-dog

cycle. Lack of control over slaughter practices and movement and trade of sheep, goats and cattle in the region may facilitate transmission of CE in the region, the prevalence of which has been estimated at 2.2–3.6% in the rural population of Xiji (Yang et al., 2009). Rural poverty and a deteriorating environment due to the rapid development of the Chinese economy have prompted policy change with respect to rehabilitating forest resources. This 'Grain to Green Programme' implemented across 25 provinces of China in 2002 aims to address ecological protection in agricultural regions by incentivising farmers to stall feed grazing animals, thus encouraging growth of forested land (Zhiyong, 2003). The aim of this study was to survey CE among livestock slaughtered at an outdoor market in this county, the prevalence of which may have been impacted by ten years of implemented change in agricultural policy. A survey of agricultural and trade practices, domestic dog ownership, and the level of local knowledge and understanding of CE was also conducted among farmers in five rural villages in Xiji in an attempt to elucidate dynamics of *E. granulosus* transmission in the region. Previous studies in the Middle East, Africa and Asia have investigated co-infections of *E. granulosus* and *Fasciolia hepatica* (Ghazaei, 2007; Berhe, 2009; Kabir et al., 2009; Berhe et al., 2011; Şakru et al., 2011) and, given that the two parasites are often co-endemic and have important economic consequences in terms of condemnation of livers, the prevalence of both species in sheep, goats and cattle were surveyed.

2. Methods

2.1. Study Sites

The study was conducted in Xiji County, Ningxia Hui Autonomous Region. Xiji County is a rural area in NHAR heavily reliant on subsistence agriculture with cultivation of cereal crops and domestic livestock the main focus of local agriculture (Yang et al., 2006a; Dai, 2010). Local residents have a low average income and the public health system is poorly resourced

and funded. The majority of the local population is educated only to junior high school level, and more than half do not have access to potable water (Yang et al., 2008; Luo and Wang, 2009; Anand, 2010). Approximately 50% of the population of Xiji County are of the Hui Islamic ethnic minority, with distinctive religious and cultural practices which may influence livestock slaughter practices in the region (Yang et al., 2006a; Xu et al., 2012). Information on the trade and slaughter of livestock was obtained from the local Animal Centre for Disease Control (ACDC) and is summarized in Table 1. The market at Xinglong Township (Xinglongzhen, Figure 1) was chosen for the examination of sheep and goats as sheep sold there were, on average, heavier and therefore more likely to be older compared to those sold at most other markets. The market was also the sixth largest in Xiji in terms of sheep sold during 2011. Examination of slaughtered cattle was undertaken at a home slaughter in Shanjiaji Village (Zhangjiez, Figure 1).

2.2. Data Collection and Carcass Inspection

Demographic information including age, village of origin, and feeding practices for each animal was collected at the time of slaughter. Tracing of animals to the home village relied on interview with animal owners or vendors at the time of slaughter. Interviews and completion of survey forms was aided by a bilingual native Chinese speaker. Because *E. granulosus* infection in livestock is highly age-dependent (Cabrera et al., 1995; Dueger and Gilman, 2001), only animals aged one year and older were eligible for inclusion. Age was determined objectively by examination of teeth eruption and wear (Moses et al., 2012). There were no other inclusion criteria. Animals for which data were collected were representative of carcasses sold for consumption at local markets where dogs would have access to infected, discarded offal. Thus, this sample is likely to be representative of slaughtered animals.

Sheep and goats were followed through the slaughter process by assigning a unique identification number to each eligible animal. The liver and lungs of each animal were systematically inspected by visual examination and palpation. Due to local slaughter practices, the liver and lungs of sheep remained inside the sheep carcass while examination was carried out.

Home slaughter of cattle was carried out by the local religious leader, and skilled butcher, the Ahong. During the butchering process, the liver and lungs were completely removed from the carcass, after which systematic visual examination and palpation of liver and lungs were carried out. The number and location of cysts consistent in appearance with *E. granulosus* metacestodes were recorded. The presence of *F. hepatica*, determined by visual inspection, was also recorded. All animal examinations were completed by a single member of the research team who had been trained by a veterinarian experienced in the detection of *E. granulosus* cysts.

The sensitivity of macroscopic examination was assessed by detailed examination of one negative liver and lung sample on each day of slaughter inspection. An organ was defined as negative for echinococcosis if there was no evidence of hydatid cysts upon macroscopic examination. Negative organs were purchased and transferred in polyethene bags directly to Xinglong Township hospital where they were dissected into 5mm subsamples and inspected for the presence of hydatid cysts. Cysts identified at the market or upon dissection were inspected for the presence of protoscoleces, then fixed in 80% (v/v) ethanol and transported to Ningxia Medical University, Yinchuan for histological confirmation.

2.3. Farmer Survey

A questionnaire was administered to local farmers regarding the species of animals kept on their farms, the number of animals slaughtered each year, herd size, the age and sex

distribution of their animals and their knowledge of CE. Questions related to factors associated with transmission included the number of domestic or stray dogs around their homes and how domestic livestock were maintained and slaughtered. Interviews were conducted by a bilingual native Chinese speaker and questionnaires completed in English. This survey was carried out in collaboration with the local ACDC and villages were sampled by convenience rather than chosen at random.

2.4. Analysis

Statistical analysis was carried out using frequency analysis. Associations between presence of liver fluke, or hepatic cysts where applicable, was carried out using a chi-square analysis with level of statistical significance set at $p \leq .05$.

3. Results

3.1. Animal Demographics

A total of 796 sheep, 200 goats and 66 cattle were slaughtered at Xinglong market or at home during the course of the survey of which 184, 13 and 55 animals, respectively, were eligible for macroscopic examination. Two thirds of sheep (61%) and cattle (65%) were aged between two and six years whereas approximately one third of goats (36%) surveyed fell within this age category. Half of the goats surveyed were aged between one and two years. The age structures of the sheep, goats and cattle surveyed are presented in Table 2. Almost half (46%) of the sheep examined came from Xinglong Township and 11% originated from Longde County, a county adjacent to Xiji County. Male sheep and cattle were more commonly slaughtered than females (56% of sheep and 80% of cattle), while 31% of slaughtered goats were male (Table 2).

3.2. Hydatid Cysts

Of the animals examined, two sheep, one cow and no goats had cystic lesions consistent in appearance with *E. granulosus;* thus the prevalence in sheep aged one year or older was estimated to be 1.0% (95%CI: 0.1–3.9%), the prevalence in cattle was 1.8% (95%CI: 0.0–9.7%) and that in goats was 0.0% (95%CI: 0.0–24.7%). All were hepatic cysts with one and two cysts present in the two sheep and more than 10 cysts visible in the cow liver. Microscopic examination of the three suspected cysts, however, failed to confirm these samples as *E. granulosus,* giving a prevalence of confirmed *E. granulosus* infection of zero percent in all three species. No cysts were detected upon dissection of organs defined as negative for echinococcosis upon macroscopic examination (N= 42).

3.3 Liver Fluke

Of the sheep surveyed, 61.3% (95% CI: 53.4 – 69.2%) showed evidence of lesions consistent in appearance with liver fluke, while 14.3% (95% CI: 0.4 – 57.9%) of goats and 12.7% (95% CI: 3.6 – 21.8%) of cattle had observable evidence of these lesions (Table 3). Liver fluke was found to be significantly associated with animal species ($p < .001$). However, among sheep, no significant associations were found between liver fluke and animal sex, age, township or type of animal feed (Table 4).

3.4 Farmer Survey

Among the 23 farmers (22 male, 1 female) from five villages surveyed, 50% were aged 45–59 years; 39% had spent 10–19 years farming, 38% had spent more than 20 years farming; and 73% had heard of CE but none knew of any attempts to control the disease in their village. Almost all households had one or more dogs with a mean of 1.3 dogs per household. Of farmers surveyed, 62% reported that meat with the appearance of being unfit for human consumption was fed to their dogs and 27% stated that meat of this appearance was simply

discarded anywhere outdoors. The assumption may be drawn from this that knowledge of *E. granulosus* is low among the surveyed community or that best practice methods for prevention of *E. granulosus* transmission is not routinely adhered to in the locality. None of the 23 farmers surveyed considered safely disposing of meat and 8% of people surveyed reported never encountering meat that looked unfit for consumption (Table 5).

The species and number of livestock kept by farmers is summarised in Table 6. The majority of sheep were female (529/760). About two fifths (39%) cattle were aged four–six years and about a quarter (23%) were aged six years and older; 74% were kept in an enclosure only and 26% were kept in both field and an enclosure. Sheep were reported to be fed a combination of grass and grain (53%), grass only (26%) or grain only (16%), suggesting that most sheep were stall-fed or grazed under supervision. All cattle were kept in an enclosure and 71% were fed both grass and grain. Approximately 775 sheep were slaughtered collectively each year by the farmers interviewed, 98.5% of which were slaughtered at a public market and the remainder home killed. All cattle were slaughtered at a local abattoir rather than at farmers' homes. The majority of sheep sent for slaughter were reportedly lambs less than 1 year old (96.6%), while half (50%) of the cattle slaughtered were less than one year old. More than one fifth of cattle slaughtered were between 2 and 4 years old (Table 6).

Discussion

In recent years, sheep and goat abattoirs run by the local government have closed due to poor health and safety conditions (Keliangbei, 2012). Trade and slaughter of sheep and goats takes place at outdoor market venues and there is little control of livestock movement and traceability in the area. Sheep and goats are usually slaughtered at open markets or private homes whereas cattle are slaughtered in private homes or abattoirs. During slaughter at open markets, the carcass is trimmed and unfit looking meat (potentially containing infective CE

cysts) is discarded on the ground where it can be scavenged by street or stray dogs. *E. granulosus* transmission may be facilitated through fecal contamination of cereal crop fields by infected dogs. Considering the high prevalence of echinococcosis in the human population of Xiji County, NHAR (Yang et al., 2006a), the absence of CE observed among commercially slaughtered livestock was surprising. Several explanations for this apparent anomaly are proposed.

Perhaps most likely, local transmission may be supported in a livestock population not captured by this survey. An abattoir survey conducted in 2005 in nearby Qinghai Province estimated the prevalence in sheep and yaks to be 82.6% and 78.5% respectively (Yu et al., 2008). Other surveys in Darlag County, Qinghai Province, have shown the prevalence to be 26.4% in sheep and 31.25% in yaks (Han et al., 2009); in neighbouring Gansu Province the prevalence is 11.1% in sheep and 19.9% in yaks (Zhao et al., 2009). Based on information collected on the origin of livestock slaughtered, and the lack of control of movement of livestock, it is possible that an *E. granulosus* reservoiris being maintained in livestock in an adjacent county or province with different livestock management or herding practices. In addition to this, the majority of sheep in our livestock sample (87.6%) were aged between one and four years and 76.4% of cattle had an age distribution of between one and four years and the number of hydatid cysts present in *E. granulosus*-infected animals generally increases with age (Cabrera et al., 1995; Gemmell et. al., 1986). Some previous studies have shown a higher CE prevalence in animals aged three years and older (Dueger and Gilman, 2001; Banks et al., 2006; Capuano et al., 2006; Beyhan and Umur, 2011; Conchedda et al., 2012; Getachew et al., 2012; Gem) whereas in other studies, prevalence has been found to be significantly higher in animals aged five years and above (Cabrera et al., 2003; Azlaf and Dakkak, 2006; Torgerson et al., 2009; Fathi et al. 2011; Zewdu et al., 2011; Melaku et al., 2012).

Alternatively it is possible that the results of this survey reflect a genuine substantial decrease in *E. granulosus* transmission in Xiji County with the current high human CE prevalence resulting from earlier exposure. A government initiated 'Grain to Green Programme' has been in effect in Xiji County since the 1990s (Pleydell et al., 2008; Dai, 2010; Yang et al., 2012). With the aim of inducing economic reform in the region, much of the land has been reforested and, as a conservation measure, restrictions have been placed on livestock herding since the year 2002. Farmers receive 100kg of grain for every 600m^2 of cropland vegetated. Grassland grazing is prohibited and violations are punished with a fine (Dai, 2010). By 2004, 97% of households in a study area in NHAR had participated in the project (Wang et al., 2010) and surface cover greenness had increased significantly by 2010 (Liu and Gong, 2012). This policy-driven change has resulted in a change in local agricultural practices. Livestock herding across grasslands has largely been replaced with stall feeding, agriculture has become more commercialised, farmers have a greater involvement in market trade and smaller herds are maintained (Dai, 2010). It has been hypothesised that environmental and anthropogenic changes in the region may have an effect on *E. granulosus* transmission (Yang et al., 2008; Yang et al., 2012), and it is reasonable to propose that this change in policy and transition away from grazing decreases the prevalence of *E. granulosus* among livestock. It is unknown whether such changes in local agricultural practices will be sustainable, should the programme cease, and what impact this might have on CE transmission.

An additional alternative explanation may be that transmission is driven by a number of ecological and socio-economic factors and is not only reliant on high prevalence among intermediate hosts. In the majority of cases, CE is asymptomatic in livestock (Eckert et al., 2001; Eckert and Deplazes, 2004) and, as a result, pastoral or rural communities are usually unaware of the dynamics of its transmission (Craig et al., 2007). From the current survey it is evident that there is little local knowledge regarding how *Echinococcus* is transmitted or

prevented despite almost three-quarters of subjects surveyed having some knowledge of the existence of the disease.

Despite the low prevalence among livestock surveyed, CE among the human population remains a problem in NHAR. The high prevalence of *F. hepatica* suggests that parasitic infections among livestock are common, although in this survey co-endemicity with *E. granulosus* could not be determined. This reinforces the recommendations of others for county-level integrated control efforts incorporating targeted education programmes, elimination of stray dogs, registration and regular deworming of family dogs, control of slaughter practices, epidemiological monitoring, and a consolidation phase of control with continuing surveillance (Gemmell et al., 1986; Economides et al., 1998; Jiménez et al., 2002; Maudlin I, 2006; Moro and Schantz, 2006; Zhang et al., 2009). Although the compliance for CE control programmes is considered challenging in pastoral communities (Craig et al., 2007), the experience with the 'Grain to Green Programme' suggests that, in the case of government implemented policy, control programmes in China may prove to be successful. Control interventions for the prevention of human CE would also be beneficial for poverty alleviation in rural, agriculturally dependent and economically poor areas (Maudlin I, 2006; Hotez et al., 2009) where diagnosis and treatment of the disease may be costly and difficult to access (Gong and Brixi, 2005; Yang et al., 2009).

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Tables

Table 1
An overview of livestock trading for market meats and population ethnicity ratios for townships in Xiji County, 2011

	Cattle			Sheep			
Township	Sold[1]	Registered[2]	Carcass weight(kg)[3]	Sold[1]	Registered[2]	Carcass weight(kg)[3]	Ethnicity ratio[4]
JiQiang	4528	7578	140	16528	11103	10	0.7:1
XingLong	9193	4133	140	6599	7674	32	12:1
PingFeng	2570	4495	140	7210	7566	15	0:1
XinYing	2198	3597	140	4407	7985	27	0.2:1
HongYao	895	687	140	5927	5053	12	0.2:1
TianPing	902	701	140	6269	6962	16	0:1
MaJian	1744	3217	140	4511	7274	23	0.8:1
SuPu	1279	2317	140	5491	5234	14	0:1
XinPing	2928	4871	140	4857	6064	19	4:1
XiTan	2444	4001	140	4593	5256	18	57:1
WangMin	2136	3553	140	7706	5267	10	2:1
ShiZI	4439	7039	140	6609	8434	20	5:1
MaLian	3013	4853	140	5541	7232	20	4:1
JiangTai	3347	6709	140	5541	6120	17	0.3:1
Xiaohe	3056	5000	140	14943	6064	6	5:1
Pianching	4353	7362	140	6258	6171	32	7:1
ShaGou	1915	3184	140	7498	6771	14	853:1
Bai'ai	2202	4964	140	6002	8206	21	1036:1
HuoshiZhai	1972	3334	140	6448	6570	16	4:1
Total *	55114	93595	140	132938	151006	17	1.3:1

[1] Number of cattle/sheep sold in the township market during 2011
[2] Number of cattle/sheep registered in the township during 2011 (young animals are not registered)
[3] Average carcass weight
[4] Ratio of Hui to Han in the township population

Table 2
Animal demographics

	Sheep	Goats	Cattle
		N (%)	
Sex			
Male	103(56.0)	4 (30.8)	44 (80.0)
Female	81 (44.0)	9 (69.2)	11 (20.0)
Age range			
1-2	52 (26.3)	7 (50.0)	13 (23.6)
2-3	33 (17.2)	1 (7.1)	19 (34.5)
3-4	44 (22.2)	2 (14.3)	10 (18.2)
4-6	43 (21.7)	2 (14.3)	7 (12.7)
6-8	8 (4.0)	1 (7.1)	2 (3.6)
8+	4 (2.0)	0 (0)	4 (7.3)
Township			
Gansu Province	2 (1.1)	-	28 (50.9)
Gongyi	5 (2.7)	-	1 (1.8)
Gu Yuan	3 (1.6)	1 (7.7)	1 (1.8)
Huoshizhai	1 (0.5)	-	-
Jiangtai	21 (11.4)	1 (7.7)	-
Longde County	21 (11.4)	2 (15.4)	1 (1.8)
Ma Lian	-	-	1 (1.8)
Shizi	15 (8.1)	1 (7.7)	2 (3.6)
Wangming	2 (1.1)	-	1 (1.8)
Xiaohe	1 (0.5)	-	-
Xiazhai	6 (3.3)	-	-
Xiji	9 (4.9)	-	9 (16.4)
Xinglong	85 (46.2)	7 (53.8)	8 (14.5)
Xing Ping	-	-	1 (1.8)
Xitan	2 (1.1)	-	-
Yuqiao	7 (3.8)	1 (7.7)	-
Indeterminate township/village	4 (2.2)	-	2 (3.6)
Total	184	13	55

Table 3
Number of livestock examined and cysts found

Animal species	**Animals slaughtered**	**Animals examined for hydatid cysts**	**Hydatid cysts**	**Location of hydatid cysts***		**Animals examined for liver fluke†**	**Liver fluke**
				Liver	**Lungs**		
	N		**% (95%CI)**	**N**			**% (95%CI)**
Sheep	Approx 796	184	1.0 (0.1 – 3.9)	2	0	150	61.3(53.4 – 69.2)
Goats	Approx 200	13	0.0 (0.0 – 24.7)	0	0	7	14.3 (0.4 – 57.9)
Cattle	Approx 66	55	1.8 (0.0– 9.7)	1	0	55	12.7 (3.6 – 21.8)

* Cysts deemed to be hydatid upon macroscopic examination, before histological confirmation

† Examination of animals for liver fluke commenced in week 3 of study

Table 4
Associations of liver fluke with animal demographics

	Liver fluke N (%)	***p*-value**
Species*		
Sheep	92 (61.3)	
Cattle**	7 (12.7)	.000
Sex		
Male	45 (56.2)	
Female	47 (67.1)	.172
Age (years)		
1	27 (62.8)	
2	12 (54.5)	
3	18 (47.4)	
4 – 6	35 (74.5)	.372
What animal ate		
Mostly grain	2 (22.2)	
Mostly grass	72 (63.2)	
Both grain and grass	16 (64.0)	.125
Township		
Xinglong	38 (55.9)	
Xiji	5 (55.6)	
Shizi	8 (66.7)	
Longde	11 (64.7)	
Jiangtai	13 (60.0)	
Gansu Province	2 (100.0)	
Other	15 (71.4)	.156

* Goats were excluded from chi-square analysis as only one goat was observed to be infected with liver fluke.
** Cattle were excluded from chi-square analysis on sex, age, animal feed and township as overall prevalence of liver fluke in this species was too small to conduct any meaningful further analysis.

Table 5
Farmer Survey Results

	Village					
	Yang He Chun	**Yuhuangou**	**Shawa**	**Yuanhe**	**Wanga**	**Total Number**
			N (%)			
Number of Farmers Surveyed	1	12	6	5	3	26
Farmer's Age						
18 – 29	0	1 (8.3)	1 (16.7)	0	0	2 (7.6)
30 – 44	0	5 (41.7)	1 (16.7)	1 (20)	0	7 (26.9)
45 – 59	1 (100)	2 (16.7)	3 (50)	4 (80)	3 (100)	13 (50)
60 +	0	4 (33.3)	1 (16.7)	0	0	5 (19.2)
Number of years spent farming						
0 – 9	0	1 (8.3)	1 (16.7)	3 (60)	0	5 (19.2)
10 – 19	1 (100)	5(41.7)	3 (50)	2 (40)	0	10 (38.5)
20 – 29	0	1 (8.3)	1 (16.7)	0	1 (33.3)	3 (11.5)
30+	0	5 (41.7)	1 (16.7)	0	1 (33.3)	7(26.9)
Number of farmers who:						
Have heard of echinococcis	0	8 (66.7)	4 (66.7)	5 (100)	2 (66.7)	19 (73)
Know of attempts to control echinococcis in their village	0	0	0	0	0	0
How meat that it is unfit to consume is disposed of:						
Throw it away anywhere	1 (100)	4 (33.3)	1 (16.7)	1 (20)	0	7 (26.9)
Dispose of it safely	0	0	-	0	0	
Feed it to the dog	0	8 (66.7)	4 (66.7)	2 (40)	2 (66.7)	16 (61.5)
Never see sick meat	0	0	0	0	2 (66.7)	2 (7.7)
Number of dogs in survey area:						
Number of dogs owned by famers	1 (100)	13	11	7	2	33
Number of stray dogs in village	0	2	2	4	0	8

Table 6
Farmer Survey Results

Village	Sheep						Cattle				
	Yang He Chun	Yuhuan-gou	Shawa	Yuanhe	Wanga	Total	Yuhuan-gou	Shawa	Yuanhe	Wanga	Total
	N (%)						N (%)				
Number of Farmers Surveyed	1	11	4	2	1	19	1	2	3	1	7
Number of Farmers who:											
Bring animals to market themselves	1 (100)	0	2 (50)	2 (100)	1 (100)	6(66.6)	1 (100)	2 (100)	1 (33.3)	1 (100)	5 (71.4)
Sell animals to a vendor	0	4 (36.4)	1 (25)	0	0	5(26.3)	0	0	2 (66.7)	0	2 (28.6)
Bring animals themselves and sell to vendor	0	7 (63.6)	1 (25)	0	0	8(42.1)	0	0	0	0	0
Number of farmers who:											
Keep animals in enclosure	1 (100)	7 (63.6)	3 (75)	2 (100)	1 (100)	14 (73.7)	1 (100)	2 (100)	3 (100)	1 (100)	7 (100)
Both in field & enclosure	0	4 (36.4)	1 (25)	0	0	5 (26.3)	0	0	0	0	0
Number of farmers who:											
Feed animals grass & grain	0	5 (45.4)	4 (100)	0	1(100)	10 (52.6)	0	2 (100)	3 (100)	0	5 (71.4)
Feed animals grass grain & corn leaves	1 (100)	0	0	0	0		0	0	0	0	0
Feed animals grass only	0	3 (27.27)	0	2 (100)	0	5 (26.3)	0	0	0	1 (100)	1 (14.3)
Feed animals grain only	0	3 (27.3)	0	0	0	3 (15.7)	1 (100)	0	0	0	1 (14.3)
Number of farmers surveyed who slaughter animals:											
At the market	1 (100)	0	0	1(50)	0	2 (10.5)	0	2 (100)	3 (100)	1 (100)	6 (85.7)
Sometimes at home/mostly at the market	0	11(100)	4 (100)	1 (50)	1 (100)	17 (89.5)	1 (100)	0	0	0	1 (14.3)
Number of animals currently owned collectively by farmers surveyed in each village											
Total	200	291	215	40	14	760	2	2	7	2	13
<1 Year	180	83 (28.5)	53 (24.6)	16 (40.0)	6 (42.9)	338 (44.5)	0	0	0	0	0
1 – 2 Years	20	64 (21.9)	0	5 (12.5)		89 (11.7)	0	0	3 (42.9)	0	3 (23)
2 – 4 Years	0	64 (21.9)	160 (74.4)	6 (15.0)	4 (28.6)	234 (30.8)	2 (100)	0	0	0	2 (15.4)
4 – 6 Years	0	64 (21.9)	0	13 (32.5)	4 (28.6)	81 (10.7)	0	0	3 (42.9)	2 (100)	5 (38.5)
6 + Years	0	16 (5.5)	2 (9.3)	0	0	18 (2.4)	0	2 (100)	1 (14.3)	0	3(23)
Number of male animals owned	0	19 (6.5)	7 (3.2)	3 (7.5)	1 (8.3)	31 (5.5)	2 (100)	1 (50)	3 (42.9)	2 (100)	8 (61.5)
Number of female animals owned	0	272 (93.5)	208 (96.7)	37 (92.5)	13 (92.9)	529 (94.5)	0	1 (50)	4 (57.1)	0	5(38.5)
Number slaughtered by farmers surveyed each year:											
Total	240	196	272	47	19	774	1	1	4	1	7
At the market	240 (100)	194 (98.9)	266 (97.8)	45 (95.8)	17 (89.5)	762 (98.5)	1 (100)	1 (100)	4 (100)	1 (100)	7 (100)
At home	0	2 (0.1)	6 (2.2)	2 (4.2)	2 (10.5)	12 (1.5)	0	0	0	0	0
Age of animals brought for slaughter											
(<1) Year	240 (100)	174 (88.8)	271 (99.6)	46 (97.8)	17 (89.5)	748 (96.6)		0.5 (50)	2 (50)	1 (100)	3.5 (50)
(1 – 2) Years	0	0	1 (0.4)	1 (0.2)	2 (10.5)	4 (0.5)	0	0	2 (50)	0	2 (28.6)
(2 – 4) Years	0	22 (11.2)	0	0	0	22 (2.8)	1 (100)	0	0	0	1 (14.3)
(4 – 6) Years	0	0	0	0	0	0	0	0	0	0	0
(6 +) Years	0	0	0	0	0	0	0	0.5 (50)	0	0	0.5 (7.1)

Figures

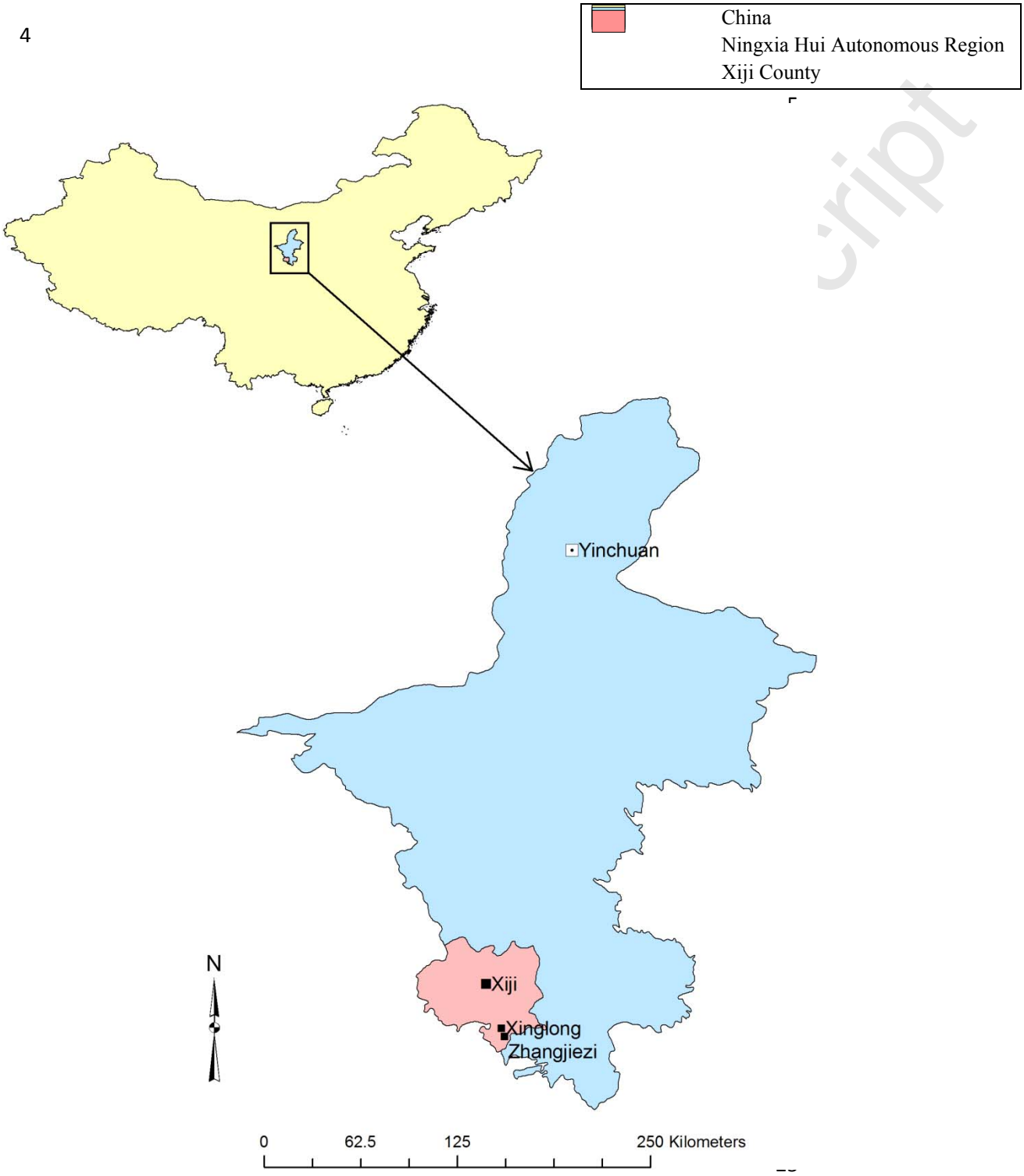

Fig. 1. Map of China with inset Xiji County, Ningxia Hui Autonomous Region.

Highlights

- Considering the high prevalence of echinococcosis in human population, but the absence of CE *observed* among commercially slaughtered livestock in Xiji County (a well known hyper-endemic area for both alveolar and cystic ehinococcosis) was surprising.
- A government initiated 'Grain to green' programme has been in effect in Xiji County since 1990s, because it has resulted in a change in local environments and agricultural practices. Therefore, we hypothesised that anthropogenic changes in the region may have an effect on *E. granulosus* transmission.
- However, the high prevalence of the *F. hepatica* suggests that parasitic infections among livestock are common, though co-endemicity with *E. granulosus* could not be determined in this survey. Several explanations for this discrepancy and their implications are proposed.